Spawning in a British Columbia Population of Northern Abalone, *Haliotis kamtschatkana*

BY

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INTRODUCTION

THE NORTHERN ABALONE (*Haliotis kamtschatkana* Jonas, 1845) has supported a commercial fishery of 500 000-1 000 000 pounds (225-450 t) annually in British Columbia since 1976. Because of interest in both management problems and artificial culture, the reproductive biology of abalones worldwide has been well studied (see MOTTET, 1978 for review). However, the spawning behaviour and season of *H. kamtschatkana* are not well described either in British Columbia or elsewhere. The season of spawning is of direct interest in regulating the fishery, especially if abalone are less valuable as a product or are more vulnerable to damage near spawning. Spawning behaviour also has some implications for management, which will be discussed below.

QUAYLE (1971) studied reproduction in this species by examining gonad sections from at least 25 individuals per month, taken from several British Columbia locations. Although his study lasted several years, he could find no demonstrable cycle, and he found ripe abalone throughout the year. Some recovering gonads were observed from April through June, and a spontaneous spawning was observed in May among individuals held in the laboratory; both suggesting natural spawning in that part of the year. Hahn (unpub. MS) studied seasonal changes in gonad index and spawning phase in this species at a California site, and found that spawning occurred in March or April of three consecutive years. As Quayle had observed, there was considerable variation around the seasonal pattern, and partially spawned individuals were found throughout the year.

OBSERVATIONS

These observations were made on 16 July 1979, on the east coast of Lyell Island (52°38.4′N; 131°27.3′W), one of the Queen Charlotte Islands. This area has been closed to commercial fishing since 1975, and has a dense population of abalone in a wide range of sizes (BREEN & ADKINS, 1979). The substrate is solid smooth bedrock, undulating over a shallow slope and broken by wide shallow crevices and patches of boulders.

Before the time that we observed spawning, we collected, tagged and replaced approximately 500 abalone by 1500 hrs. Plastic spaghetti tags (Floy Tag Company, Seattle) were threaded through two respiratory pores and tied. This operation was carried out on board a nearby boat concurrently with collecting. Tagged abalone were replaced as new collections were made, so that abalone were returned and replaced within a couple of hours from the time they were removed.

During our collecting, we noticed that the abalone appeared to be unusually weakly attached to the substrate. Ordinarily we remove abalone by inserting a dull-edged diving knife under the lateral edge of the foot and twisting it, which dislodges the animal from its substrate quickly and without injury if done carefully. Normally it is possible to 'surprise' only a small proportion of abalone and remove them with a simple lateral push before they clamp more firmly to the rock. On this day, however, almost all abalone were very loosely attached, and we collected them by simply picking them off the rock with our hands.

The gonads of most individuals collected were large and turgid. Whereas handling usually causes abalone to retract

the foot tightly into the shell, these individuals remained relaxed but active, allowing easy marking and examination. Many of the males exuded sperm during the tagging process.

In the early afternoon, we observed a general spawning in progress at the collection site. More than half the abalone were involved. Many had formed close aggregations in which only one was attached to the rock, the rest being attached to that one or to others in turn attached to the bottom one. The largest group observed contained six individuals. The uppermost abalone were sometimes 20-25 cm above the substrate to which the lowermost was attached. All individuals seemed only loosely attached to the rock or each other, and nearly all in such groups were spawning. Individual spawners of both sexes were also observed. Some of these were near non-spawners, but others were alone. Tagged as well as untagged individuals were spawning; tagged individuals comprised no more than about 20% of the whole population within the area we examined. Females spawned at intervals of 15-120 sec. by releasing sharp puffs of eggs, clearly visible. Male spawning was slower, more continuous and less active, punctuated by irregular strong pulses of sperm.

Most of the spawning groups, and also many single spawners, had reached the highest point available in their immediate area: usually this was a ridge of bedrock or a boulder top. We found a pair of individuals approximately 1 m from the bottom on a stipe of bull kelp (*Nereocystis luetkeana*). In addition, many had raised their bodies as far from their substrate as possible. Spawning was first observed at 1500 h and was still in progress at 1830 h when our last dive was made.

The weather at the time was sunny, calm, and hot. The previous day had been the same; several days before that had been overcast but calm. Water temperature could unfortunately not be measured, but we estimated surface temperature to be greater than 15° C. There was no sharp thermocline within the depths we observed, but the surface was noticeably warmer. The collecting site was located 2-5 m below chart datum, and in 3-9 m actual depth. LLW occurred at noon. The moon was in last quarter, and so LLW was between its minimum and maximum for this cycle. Visibility was at least 12 m in the early morning, but in the afternoon had decreased to 2-3 m. This may have been partly as a result of the spawning, but we had observed decreasing visibility with rising tides on previous dives nearby.

A small percentage of male red sea urchins [*Strongylocentrotus franciscanus* (A. Agassiz, 1863)], limpets [*Collisella ochracea* (Dall, 1871)], and serpulid worms (*Serpula vermicularis* Linnaeus, 1767) were also observed spawning, but no spawning females of these species could be found.

Evening plankton tows were made at this location two and three days after spawning was observed, but no veligers were found. On 18 July at a nearby site, both males and females exuded gametes during tagging, and 8-cell larvae were obtained several hours after these were mixed in dishes.

DISCUSSION

Our activities may have triggered this spawning. The abalone we collected and replaced were all disturbed by handling and being exposed to the warm air for varying periods up to 30 min. Mottet (1978) reported handling and exposure as natural spawning stimuli. Liberation of sperm is a common occurrence when abalone are disturbed, and many of the males we handled exuded sperm during marking. If they continued to do so when replaced, then a considerable quantity of sperm must have been liberated. The presence of sex products in the water is also reported as a natural trigger for spawning (Carlisle, 1945), and thus marked animals may have stimulated the rest of the population to spawn. In any case, externally the abalone appeared ripe, and their uncharacteristic behaviour may have been preliminary to a completely natural spawning.

The temperature experienced by an abalone at this place would have been lowest in the morning, rising as the tide fell, with a maximum near noon; then falling again as the tide changed. If tidal temperature rhythms are a common trigger for spawning in this species, then the season of spawning might vary greatly, depending on local weather conditions. Oysters in Pendrell Sound, British Columbia, whose spawning is triggered by surface temperature, have spawned from early June to late August in different years (Quayle, 1974). Whatever the reason, wide variability in reported spawning season appears to be the rule in most abalone species world-wide (Mottet, 1978).

The small but unusual aggregations we observed, in which abalone were climbing on top of one another, have not been reported before. Aggregation might easily function as a mechanism for ensuring maximum contact between eggs and sperm, and hence a high fertilization rate. Kikuchi *et al.* (1974) report that optimum fertilization is obtained at sperm densities of 100 000 - 1 900 000/mL. Dilution of sperm below this concentration would take place at a relatively small distance from spawning males.

The size and number of spawning groups indicate that they have a strong adaptive role, as suggested above. If so, then severe decreases in local density might have a strong

effect in reducing recruitment rate, beyond that expected from the simple reduction in the number of spawning adults. We estimate that the British Columbia abalone fishing has reduced the mean density of Queen Charlotte Islands abalone above 102 mm length by 75% since 1975 (Breen, 1980). At many sites, more drastic decreases have occurred. Recruitment failures as a result of intense harvesting are thus not surprising.

The tendency for abalone to be as high up as possible during spawning was also reported by Quayle (1971), and Ino (1966) reported upward vertical migration before spawning in *Haliotis discus hannai*. He observed that abalone spawning in laboratory tanks were all near the top of the water, and that some even crawled out of the tanks and fell onto the floor. This behaviour may be an indirect mechanism for aggregation, as adult density is greatest in shallow water in this part of British Columbia (Breen & Adkins, 1979). Alternatively, it could act as a mechanism for releasing the eggs in the warmest water available; or, finally, it could act as another mechanism for ensuring high fertilization rate. Eggs released from a high place, where they fall through a water column before coming to rest on the bottom, might be exposed to more sperm than eggs which fall to the bottom immediately after being spawned.

These observations extend the known spawning season of *Haliotis kamtschatkana* in British Columbia into midsummer.

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